Radiation Physics Note #77
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DETERMINATION OF THE SITE BOUNDARY DOSE DUE TO RAILHEAD RADIONUCLIDE STORAGE AT FERMILAB

The problem of assessing the dose level at the Fermilab site boundary due to our radionuclide storage facility is one of those tasks which is easy in principle but difficult in practice. It is a problem intrinsically tied to the methodology of making reliable measurements of low level radiation fields and accurately assigning an ambient background; ambient background very often being a strong function of location. Estimating the site boundary dose due to our radiation storage facility has involved manipulating these elements in such a way as to generate a reasonable and consistent estimate.

A reasonable estimate of the railhead contribution to the site boundary dose can be made by making use of several different detectors which compliment each other in their measurement capabilities, and by assuming that the multiple sources present in the railhead can be approximated as a point source at large distances from the boneyard storage cave.

1. The Bicron NaI detector seems to be useful for establishing a region where the $1/r^2$ law holds and a correction factor for $1/r^2$ extrapolation from the Hippo to a more distant point. However it is probably not useful for an accurate determination of the site boundary dose from the railhead due to significant normalization uncertainties. When calibrated against the dose observed by the Hippo, the calibration factor for the Bicron is determined to be 7.54×10^5 cpm/mR/hr. The

calibration factor determined by IMAC using a ^{137}Cs source was 3.6×10^5 cpm/mR/hr. A calibration factor of 1.2×10^5 cpm/mR/hr is obtained by comparing an average count rate near the guard house at the entrance to the railhead area with the ten year average background for the Western Suburbs from an Argonne National Laboratory report (Ref. 1). Thus, when the Bicron count rate is extrapolated to the site boundary there is no reliable normalization factor for converting that reading into a dose. This is partly due to the fact that the Bicron NaI detector may be as much as 2.5X more sensitive to the radiation field it sees at the site boundary than it is to the one it sees at the Hippo. In fact, the Bicron detector is ~2.1 times more sensitive to a 200 keV dominated radiation field than it is to the 650 keV dominated radiation field of a ^{137}Cs source, i.e., sensitivity of a NaI detector to gamma radiation is strongly energy dependent. Normalization uncertainties are also partly the result of the lower level discriminator threshold on the Bicron detectors. The relative percentage of the gamma radiation field lost at the hippo due to this threshold could be vastly different from the relative percentage lost at the site boundary. Since the functional dependence of an environmental radiation field on wavelength can vary considerably from place to place, the Bicron survey meter is not a prudent choice for dose assessment from such fields.

When radiation from the railhead dominates the spectrum, the Bicron measurements can be used to assess the region of validity for the $1/r^2$ law though not for assessing actual dose. A Bicron survey taken on November 23, 1988 yielded the following results for count rate versus distance from the Boneyard storage cave:

Reading (cpm)	Distance from Cave (ft)
70,000	40
55,000	60
45,000	80
100,000	100
21,000	140
13,000	187
11,000	227
9,000	267
5,000	400
3,200	650

This leads to $1/r^2$ functional behavior beginning at ~300' and a projected count rate at the site boundary, located a distance of 1238 ft from the Boneyard cave, of 303 cpm above an assumed 2100 cpm background. Projected count rate above background at the nearest house, located at a distance of 2722 ft. from the Boneyard cave, would be:

$$CR_{house} \simeq 2.9 \times 10^3 \text{ cpm } \left(\frac{4 \times 102}{2.722 \times 10^3}\right)^2 \simeq 63 \text{ cpm}$$

Using the boneyard cave as a point source, a correction factor for $1/r^2$ extrapolations from the Hippo to the site boundary, can be graphically estimated (see Fig. 1). This factor corrects for the multiple source contributions seen at the Hippo but not the site boundary. When the distance from the boneyard cave is plotted against the observed Bicron count rate, minus an assumed background of 2100 cpm on a log-log scale, the points appear to fall on a straight line with a slope of -2 from 130 ft. to the site boundary. At the site boundary the extrapolated count rate is then 303 cpm. If we now draw a line parallel, i.e., with a slope of -2, to the best fit line but going through the point at the Hippo, then we find an estimated count rate of 248 cpm. It can thus be concluded that doses extrapolated from the Hippo to the site boundary

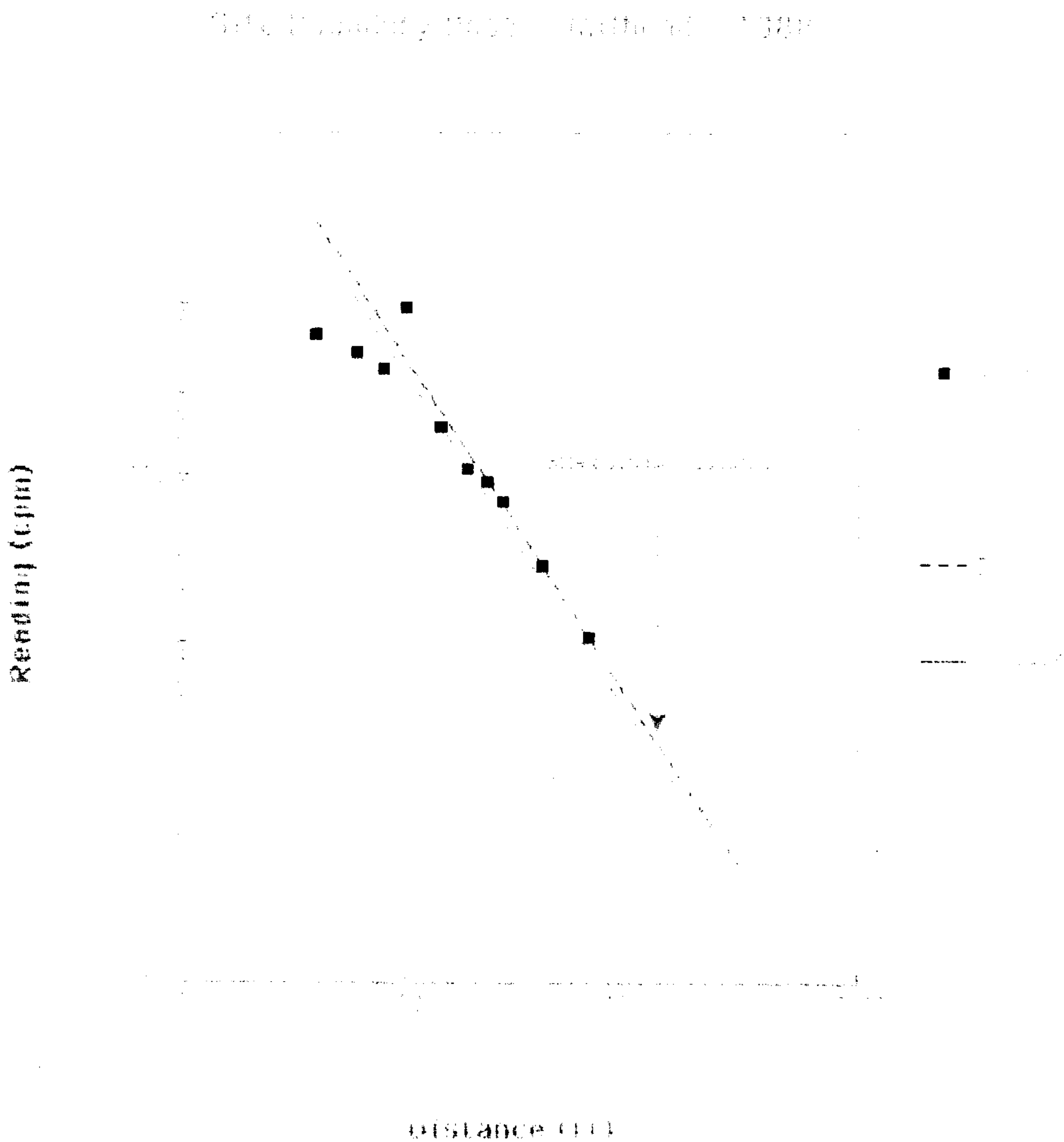

Figure One

using an $1/r^2$ functional dependence should be corrected by the factor 303/248 = 1.222.

2. The railhead Hippo has no lower level electronics cutoff and therefore sees all radiation passing through it which ionizes the detector gas. It is left in the railhead area year round with readings taken once a week. The average of the readings was 2.8969 mrem/wk. or 150.6 mrem/yr.; a very reasonable number. Another Hippo detector, located at Site 3, yielded an average weekly reading of 1.9452 mrem/wk. or 101.2 mrem/yr. Again this number is in good agreement with the known average background for this area. Subtracting these two numbers, extrapolating from the Hippo to the site boundary, and applying the 1.222 correction factor gives an estimated site boundary dose of 1.38 mR/yr. from the railhead storage area. Dose at the nearest house is then estimated to be 0.29 mR/yr. from the railhead storage area.

3. The environmental TLD's were changed to $CaSO_4$:Dy this year and seemed to work very well. The average TLD reading near the Hippo was 56±16 mrem/yr. above an assumed background of 104 mrem/yr. by the vendor. When extrapolated to the site boundary from the Hippo and corrected, the site boundary dose due to the railhead is estimated to be 1.56±0.45 mR/yr. and the dose at the nearest house is estimated to be 0.32±0.09 mR/yr. Both of these numbers agree well with the Hippo determination and the peripheral numbers such as the ambient background agree well with other independent measurements such as those by Argonne. If these numbers are reasonable estimates of the ambient background and the railhead contribution at the site boundary, then the TLD measurements at

the 3 site boundary locations indicate the presence of at least one other significant source of radiation between the railhead ditch and the site boundary.

Site Boundary TLD ID#	Average Dose Above Nominal Region Bkgd (mrem/yr.)	Dose Unaccounted for by Railhead (mrem/yr.)
#5	26±7	24.5±7
#6	30±8	28.5±8
#7	16±6	14.5±6

Results of the Bicron survey tend to support this speculation, in that, elevated count rates were observed near the fence separating the railhead ditch from the corn field (TLD #2) and also at the site boundary, that were most probably not due to the nominal region background or the railhead. This source is not believed to be accelerator produced since it is outside of the railhead. It is possible that it is natural radioactivity from fertilizer applied to the corn field.

Conclusion

I conclude from all this analysis that the most reasonable estimate of the dose at the site boundary due to the railhead storage area is 1.6±0.5 mrem/yr. At the nearest house it can be estimated as 0.3±0.1 mrem/yr. It is clear from these numbers that the railhead storage area does not present a significant radiation hazard to the general public.

References

1. N.W. Golchert, T.L. Duffy, and J. Sedlet, Environmental Monitoring at Argonne National Laboratory - Annual Report for 1983, National Technical Information Service, U.S. Department of Commerce, ANL-84-14.